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RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

SUPPLEMENTARY INVESTIGATION IN THE LANGLEY
FREE-SPINNING TUNNEL OF A 1/20-SCALE MODEL OF THE
DOUGLAS XF4D-1 AIRPLANE INCLUDING SPIN-RECOVERY
PARACHUTE TESTS OF THE MODEL LOADED TO
SIMULATE THE DOUGLAS F5D-1 AIRPLANE

TED NO. NACA AD 3116

By Walter J. Klinar and Henry A. Lee

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SUMMARY

A supplementary investigation has been conducted in the Langley 20-foot free-spinning tunnel of a 1/20-scale model of the Douglas XF⁴D-1 airplane to determine the effect of only neutralizing the rudder for recovery from an inverted spin, and the effect of partial aileron deflection with the spin for recovery from an erect spin. An estimation of the size parachute required for satisfactory recovery from a spin with the model ballasted to represent the Douglas F5D-1 (formerly the Douglas XF⁴D-2) airplane was also made. Results of the original investigation on the XF⁴D-1 design are presented in NACA RM SL50K30a.

The results indicated that satisfactory recoveries from inverted spins of the airplane should be obtained by rudder neutralization when the longitudinal stick position is neutral or forward. Recoveries from erect spins from the normal-spin control configuration should be satisfactory by full rudder reversal with simultaneous movement of the ailerons to two-thirds with the spin. For the parachute tests with the model loaded to represent the F5D-1 airplane, the tests indicated that a 16.7-foot-diameter hemispherical-tail parachute (drag coefficient of 1.082 based on the projected area) with a towline 20.0 feet long (full-scale values) should be satisfactory for an emergency spin-recovery device during demonstration spins of the airplane.

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INTRODUCTION

Because of pilot confusion during a recent spin test demonstration of an XF⁴D-1 airplane the controls were moved improperly for spin recovery, and it became necessary for the pilot to use the spin-recovery parachute to recover from an inverted spin. Spin-tunnel tests conducted previously on a model of the XF⁴D-1 (ref. 1) had indicated that rudder reversal to full against the spin should satisfactorily terminate inverted spins. In order to avoid pilot confusion in applying the rudder in inverted spins, however, it would appear desirable merely to neutralize the rudder, provided this movement would lead to satisfactory recoveries. Accordingly, supplementary tests were undertaken on the available 1/20-scale model of the Douglas XF⁴D-1 airplane in the Langley 20-foot free-spinning tunnel to determine whether neutralization of the rudder would satisfactorily terminate inverted spins. In addition, some erect spins were conducted on the model to determine whether partial movement of ailerons to with the spin would be sufficient to insure recovery from erect spins. (Previous results presented in reference 1 indicated that full aileron movement to with the spin would satisfactorily terminate erect spins but that aileron movement to only one-third with the spin was inadequate.) Tests were also conducted on the XF⁴D-1 spin model loaded to simulate the F5D-1 loading to determine the size parachute required for emergency recovery from demonstration spins for the F5D-1 airplane. (The XF⁴D-1 and F5D-1 airplanes are fairly similar dimensionally.)

SYMBOLS

b	wing span, ft
S	wing area, sq ft
\bar{c}	mean aerodynamic chord, ft
x/\bar{c}	ratio of distance of center of gravity rearward of leading edge of mean aerodynamic chord to mean aerodynamic chord
z/\bar{c}	ratio of distance between center of gravity and fuselage reference line to mean aerodynamic chord (positive when center of gravity is below line)
m	mass of airplane, slugs
I_X, I_Y, I_Z	moments of inertia about X, Y, and Z body axes respectively, slug-ft ²

$\frac{I_X - I_Y}{mb^2}$	inertia yawing-moment parameter
$\frac{I_Y - I_Z}{mb^2}$	inertia rolling-moment parameter
$\frac{I_Z - I_X}{mb^2}$	inertia pitching-moment parameter
ρ	air density, slug/cu ft
μ	relative density of airplane, $\frac{m}{\rho S b}$
α	angle between fuselage reference line and vertical (approximately equal to absolute value of angle of attack at plane of symmetry), deg
ϕ	angle between span axis and horizontal, deg
V	full-scale true rate of descent, ft/sec
Ω	full-scale angular velocity about spin axis, rps
D	parachute drag, lb
S_p	projected area of hemispherical parachutes or laid-out-flat area of flat-type parachute, sq ft
q	dynamic pressure, lb/sq ft
C_D	parachute drag coefficient, $\frac{D}{q S_p}$

APPARATUS, METHODS, AND PRECISION

The 1/20-scale model of the Douglas XF4D-1 airplane used for the original investigation (ref. 1) was used for the present investigation. A three-view drawing of the model is shown in figure 1. The testing technique and precision were essentially the same as those given in reference 1.

Lateral and longitudinal controls were combined in one pair of control surfaces called elevons. Longitudinal control was obtained by deflection of the elevons in the same direction and lateral control was obtained by deflection of the elevons differentially. However, in this paper, elevon deflections for longitudinal and lateral control will be referred to, for simplicity, as elevator and aileron deflections, respectively. The model was also provided with small control surfaces called trimmers located at the trailing edge of the wing inboard of the elevons. (See fig. 1.)

TEST CONDITIONS

The mass characteristics and inertia parameters for the normal loading conditions of the XF⁴D-1 and F5D-1 airplanes and for the normal loading conditions simulated on the model are given in table I. Tests were conducted for the XF⁴D-1 normal loading to determine the effect of rudder neutralization on recoveries from inverted spins and to determine the effect of moving ailerons to only two-thirds with the spin for recovery from erect spins. The model was ballasted to a simulated spin test altitude of 15,000 feet. As previously indicated, parachute-recovery tests were conducted with the model loaded to simulate the F5D-1.

The maximum control deflections (perpendicular to the hinge lines) used in the present tests were similar to those used in the investigation reported in reference 1 and were as follows:

Rudder, deg	30 right, 30 left
Elevators, deg	20 up, 15 down
Ailerons, deg	15 up, 15 down
Trimmers, deg	30 up, neutral

RESULTS AND DISCUSSION

The results of the erect and inverted spin tests for the XF⁴D-1 in the normal loading are presented in charts 1 and 2. The parachute recovery tests for the model loaded to simulate the F5D-1 normal loading are presented in table II. The results to the right and left were similar and are arbitrarily presented in terms of spins to the pilot's right.

XF4D-1 Normal Loading

Inverted spins.-- The results of the inverted spin tests for the XF4D-1 normal loading (loading 1 in table I) are presented in chart 1. The order used for presenting the data for inverted spins shows controls crossed for the established spin (right rudder pedal forward and stick to pilot's left for a spin to pilot's right) at the right of the chart and stick back at the bottom. When the controls are crossed in the established spin, the ailerons aid the rolling motion; when the controls are together, the ailerons oppose the rolling motion. The angle of wing tilt ϕ in the chart is given as up or down relative to the ground.

As is shown on chart 1, the inverted spins were oscillatory in nature as was previously indicated in chart 6 of reference 1. The information presented in chart 1 indicates that rudder neutralization should lead to satisfactory recoveries from inverted spins for neutral and full-forward positions of the stick from aileron-neutral spins or from spins with controls together in the developed inverted spin (stick right in an inverted spin to pilot's right). Although no tests were conducted from the inverted spins with controls crossed, stick left in an inverted spin to pilot's right, information presented in reference 1 indicates that recoveries attempted by rudder neutralization for this lateral position of the stick should be as good as or better than those obtained for the lateral stick positions investigated. Longitudinal positions of the stick rearward of neutral should be avoided inasmuch as recoveries by rudder neutralization for these stick positions may be unsatisfactory.

Erect spins.-- Results of some brief erect spin tests conducted using a combined control movement consisting of aileron movement to two-thirds with the spin and rudder reversal are presented in chart 2. The results presented in chart 2 are generally for trimmers set at neutral but some tests were also conducted with trimmers set 35° up for ailerons displaced one-third against the spin (in the adverse direction) and the elevator set to two-thirds full up (the criterion spin setting) because the model was easier to maintain in the spin for this trimmer setting. As was indicated in the previous investigation (ref. 1), for aileron-neutral or against settings, either the model would not spin erect or would spin in an oscillatory manner; for aileron-with settings, only very steep spins were obtained. The results of the model tests indicated that recoveries from fully developed erect spins on the airplane should be satisfactory from the normal spin control configuration (rudder full with the spin, elevator full up, and ailerons neutral) if full rudder reversal is accompanied by simultaneous movement of the ailerons to two-thirds with the spin. Recoveries attempted by the above control manipulation from fully developed erect spins with ailerons full against the spin, however, should be unsatisfactory. In order to allow

for possible scale effects and pilot inconsistencies in moving controls to their specified positions, it is felt that optimum control technique should include aileron movement to full with the spin and that precautions should be taken during the recovery to avoid rolling into an inverted spin. It should be noted that, for the model tests wherein the model recovered after control movement, the ensuing motion was a dive or a glide. The test data presented in reference 1 indicate that the model recovered in a dive or glide after movement of ailerons to with the spin if elevators and/or trimmers were maintained full up, whereas neutral and down positions of elevators or down settings of the trimmers were likely to result in aileron rolls after movement of ailerons. In order to increase the possibility of recovering in a glide rather than in an aileron roll after movement of ailerons to with the spin for recovery from erect spins and thereby enable a pilot to ascertain more readily that the spin has been terminated, it is recommended that the trimmers be placed full up and that the elevator be maintained full up until recovery is imminent.

Spin-Recovery Parachute Tests For F5D-1 Normal Loading

The results of the spin-recovery parachute tests are presented in table II. The tests were performed for both erect and inverted spins. The center of gravity was moved forward of normal for these tests because brief tests had indicated that it would be easier to obtain erect spins on the model for a forward center-of-gravity position. Difficulty was experienced in keeping the model in erect spins even for this loading, however, and, consequently, the recovery attempts from the erect spins were made while the model still possessed some of its launching rotation and before the model oscillated out of the spin. The inverted spins were oscillatory but the model remained in the inverted spin and was controllable in the tunnel. For the tests the towline was attached at the rear of the fuselage just above the jet exhaust. It was found that a hemispherical parachute with a projected diameter of 16.7 feet and a towline length equivalent to 20 feet (full-scale values) should be satisfactory for recoveries from both the erect and inverted spins. The distance between the inflated canopy and the point of attachment on the fuselage was 52 feet, full scale. The above was a stable-type parachute with a drag coefficient of 1.082 based on the projected area. If a parachute with a different drag coefficient is used, a corresponding adjustment will be required in parachute size. Reference 2 indicates that conventional flat parachutes made of low-porosity materials are unstable and may seriously affect the stability of the airplane in normal flight when the parachute is opened to test its operation. It may be desirable, therefore, to use a stable parachute (ref. 2) as an emergency spin-recovery device on the full-scale airplane.

CONCLUSIONS

Based on the results of tests of a 1/20-scale model of the Douglas XF4D-1 airplane ballasted to a simulated altitude of 15,000 feet, the following conclusions are drawn:

1. Satisfactory recoveries from inverted spins will be obtained even if the rudder is only neutralized when the longitudinal stick position is neutral or forward.
2. Satisfactory recoveries from erect spins will be obtained by full rudder reversal in conjunction with simultaneous movement of the ailerons to two-thirds with the spin for spins entered with ailerons near neutral. Optimum control technique, however, should include aileron movement to full with the spin. Care should be exercised during the recovery to avoid rolling into an inverted spin.
3. An estimate made with the model loaded to simulate the F5D-1 indicated that a stable hemispherical parachute with a projected diameter of 16.7 feet and a towline length of 20 feet ($C_D = 1.082$) should be satisfactory for emergency recoveries from demonstration spins on the F5D-1 airplane. If a flat-type parachute or a hemispherical parachute with a different drag coefficient is used, a corresponding adjustment will be required in parachute size.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., November 21, 1955.

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1. Lee, Henry A.: Free-Spinning and Tumbling Characteristics of a 1/20-Scale Model of the Douglas XF4D-1 Airplane as Determined in the Langley 20-Foot Free-Spinning Tunnel - TED NO. NACA DE 346. NACA RM SL50K30a, Bur. Aero., 1950.
2. Scher, Stanley H., and Draper, John W.: The Effects of Stability of Spin-Recovery Tail Parachutes on the Behavior of Airplanes in Gliding Flight and in Spins. NACA TN 2098, 1950.

TABLE I

MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR THE NORMAL
LOADINGS ON THE DOUGLAS XF4D-1 AND F5D-1 AIRPLANES AND
FOR THE LOADINGS TESTED ON THE 1/20-SCALE MODEL

[Model values are given as corresponding full-scale values; moments of inertia are given about the center of gravity]

No.	Model	Loading	Weight, lb	Center-of-gravity location		Relative density, μ		Moments of inertia, slug-feet ²			Mass parameters		
				x/\bar{c}	z/\bar{c}	Sea level	Altitude of 15,000 ft	I_X	I_Y	I_Z	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$
Airplane values													
1	XF4D-1	Normal gear up	16,821	0.236	0	11.77	18.72	10,346	31,492	40,630	-361×10^{-4}	-156×10^{-4}	517×10^{-4}
2	F5D-1	Normal gear up	21,786	.221	-----	15.25	24.24	13,780	57,201	68,945	-572	-155	727
Model values													
1	XF4D-1	Normal gear up	17,026	0.228	-0.011	11.92	18.95	10,732	32,197	41,663	-362	-159	521
2	XF4D-1 with F5D-1 loading simulated	Normal gear up	23,695	.149	.170	16.58	26.36	15,517	66,835	78,810	-622	-145	767

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TABLE II

SPIN-RECOVERY PARACHUTE DATA FOR MODEL LOADED TO SIMULATE THE
F5D-1 AIRPLANE NORMAL LOADING

[Loading no. 2 on table I; recovery attempted by opening parachute only;
model values converted to corresponding full-scale values]

Parachute diameter, ft (a)	Towline length, ft	Drag Coefficient, C _D (a)	Parachute stability	Type of parachute	V, ft/sec	Control setting maintained during spin and recovery				Turns for recovery
						Rudder	Elevator	Aileron	Trimmer	
Erect Spins										
14.2	20.0	1.026	Stable	Hemispherical	209	Full with	Full up	Full against	Full up	1½, 2, 2½
15.0	20.0	.626	Unstable	Flat	209	Full with	2/3 up	1/3 against	Neutral	>3, >4, >8
16.7	20.0	1.082	Stable	Hemispherical	209	Full with	Full up	Full against	Full up	1, 1¼, 1½, 2
Inverted Spins										
12.5	20.0	.922	Stable	Hemispherical	209	Full with	b2/3 down	c1/3 against	Neutral	1½, 2¾, 3½, 4½
14.2	20.0	1.026	Stable	Hemispherical	209	Full with	b2/3 down	c1/3 against	Neutral	2¼, 2½, 2¾, 3
16.7	20.0	1.082	Stable	Hemispherical	209	Full with	b2/3 down	c1/3 against	Neutral	1½, 1¾, 2

^aFor the flat-type parachute the diameter is given for the laid-out-flat area and the drag coefficient is based on this area. For the hemispherical parachute the projected diameters are given and the drag coefficient is based on the projected area.

^bDown given relative to the pilot.

^cRudder and ailerons together in the established inverted spin.

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CHART 1 .-SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

[Recovery attempted by rudder neutralization (recovery attempted from, and developed-spin data presented for, rudder full-with spins)]

Airplane XF ₄ D-1	Attitude Inverted	Direction To pilot's right	Loading (see table I) Normal gear up		
Slats	Flaps	Stabilizer	Speed brakes		

Model values converted to full scale

U—inner wing up

D—inner wing down

a

36 54	16U 22D
197 252	0.27
b $\frac{1}{2}$	b 1

a,c

216 240	0.22
b $\frac{1}{4}$	b $\frac{1}{2}$

a

37 56	3D 20D
222	0.28
a 1,	d $1\frac{1}{4}$

Stick right
(Controls together)

a

STEEP SPIN	
App. 234 298	
e $\frac{3}{4}$	e $\frac{3}{4}$, 1, 2

Stick left
(Controls crossed)

^aVery oscillatory spin. Range of values or average values given.

^bRecovered in an inverted glide.

^cNo spin also obtained.

^dRecovered in an aileron roll.

^eRecovered in an inverted dive.

^fRecovery attempted before model reached final steep attitude.

^gVisual estimate.

Stick back

a

STEEP SPIN	
234 298	
g >2,	g >3, >3

α (deg)	ϕ (deg)
V (fps)	Ω (rps)
Turns for recovery	

CHART 2.-SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

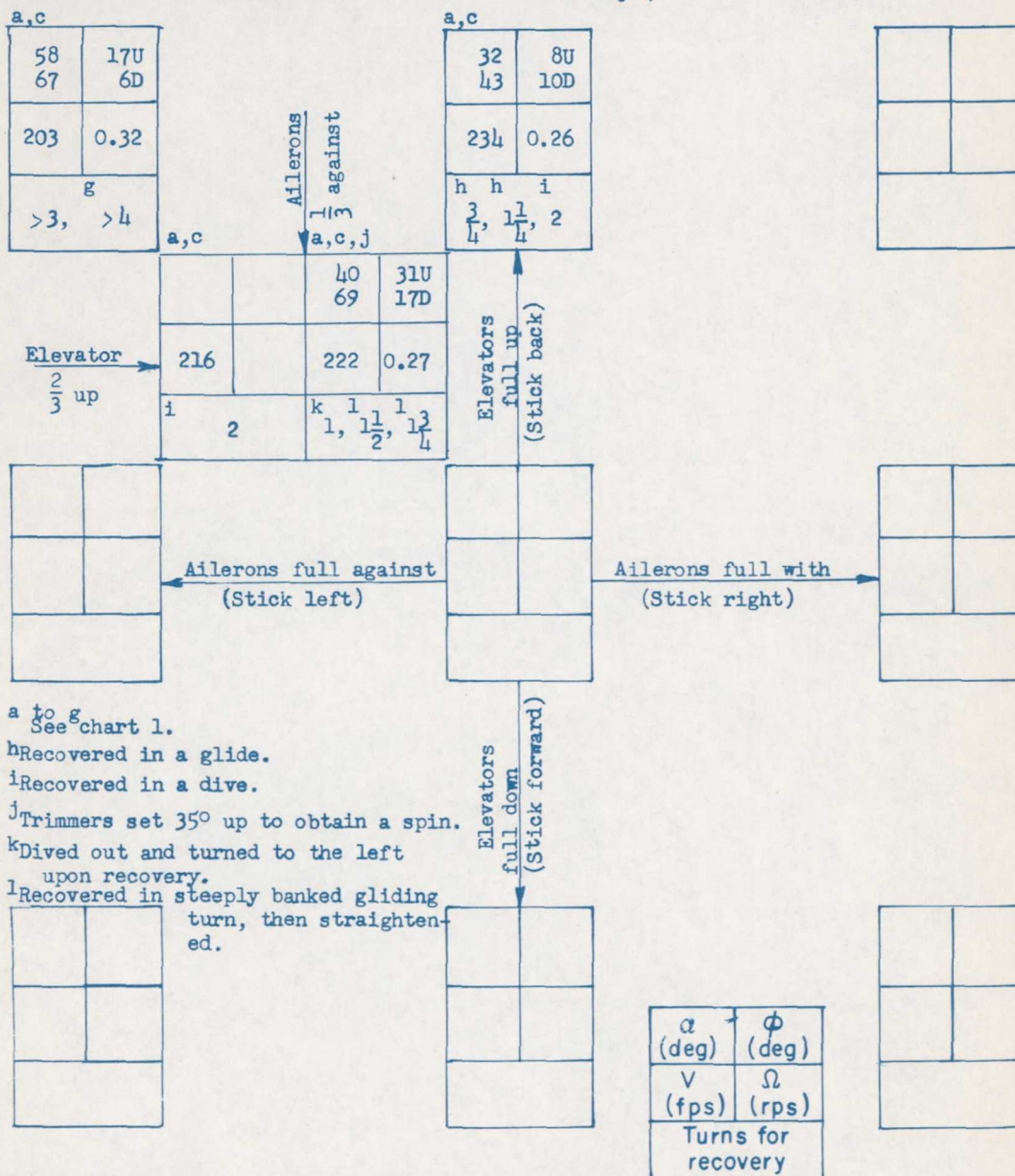
[Recovery attempted by full rudder reversal accompanied by aileron movement to $\frac{2}{3}$ with the spin (recovery attempted from, developed-spin data presented for, rudder $\frac{2}{3}$ full-with spins)]

Airplane XF4D-1	Attitude Erect	Direction Right	Loading (see table I) Normal gear up	
Slats	Flaps	Stabilizer	Speed brakes	Trimmers Neutral except as noted

Model values converted to full scale

U—inner wing up

D—inner wing down



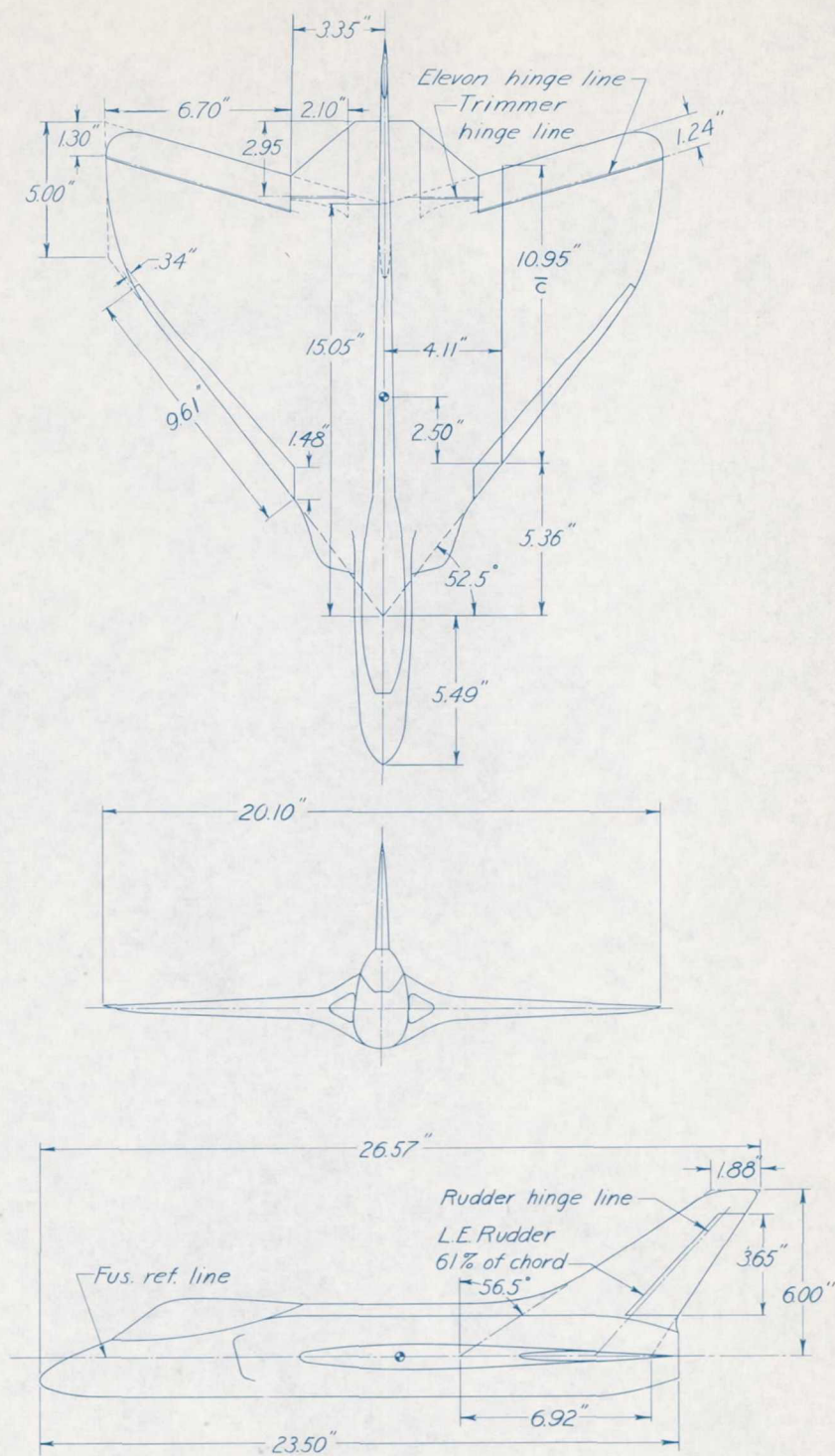


Figure 1.- Three-view drawing of the 1/20-scale model of the Douglas XF4D-1 airplane as tested in the Langley 20-foot free-spinning tunnel. Dimensions are model values. Center-of-gravity position shown is for the normal condition.

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